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ABSTRACT

Drainage for land treatment sites must be evaluated with respect to the purpose the system is meant to achieve. Off-site drainage controls the flow of storm runoff onto the site or groundwater incursion into the soil within the site. On-site drainage is employed for a variety of reasons. These two areas of drainage control must be designed as a system to obtain the desired effluent quality from the land treatment system. Surface drainage techniques often used for the control of water include diversions, random surface drains, waterways, and ditches. Subsurface drainage is generally accomplished through the use of drain piping with materials such as plastic, clay, and concrete. These techniques will generally make up the drainage system. The objectives of drainage systems as they relate to land treatment sites are discussed, including some flexible operating patterns which can be incorporated through the use of on-site drainage. (Author/BB)

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ED162838

# Land Application of Wastes

An Educational Program

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DRAINAGE FOR LAND APPLICATION SITES

Module 21

January, 1978

SE 025 035

LAND APPLICATION
OF WASTES -
AN EDUCATIONAL PROGRAM

The objective of this program is to increase the knowledge of engineers, scientists, waste management specialists and other practitioners in the concepts and principles needed to properly utilize the potential of land for the application of wastes. It is designed for individuals concerned with waste disposal alternatives for municipal, industrial, and agricultural wastes. The modules in this Program incorporate knowledge from sanitary and environmental engineering, agronomy, soil science, agricultural engineering, economics, and law.

The program consists of some twenty-five modules and audio-visual materials as appropriate.

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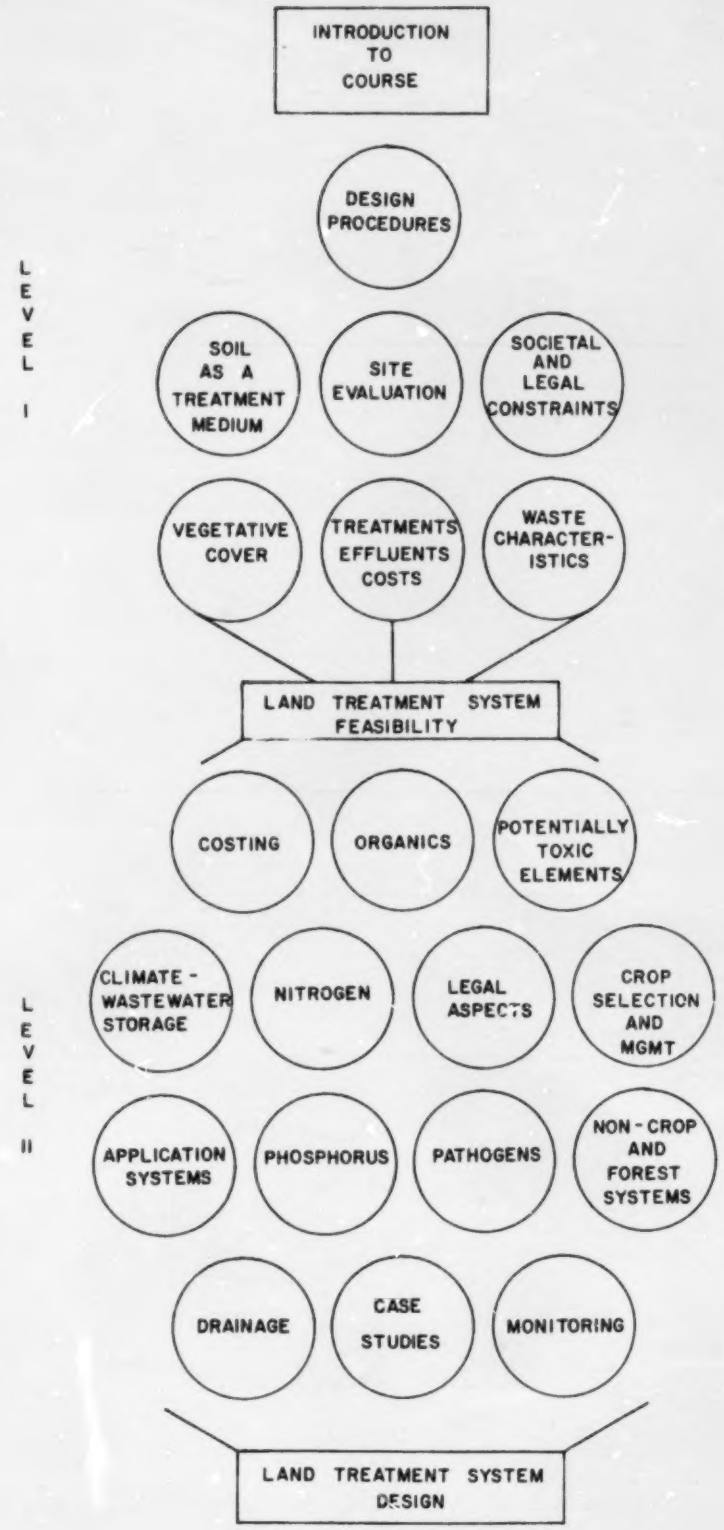

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DRAINAGE FOR LAND APPLICATION SITES

Module 21

January, 1978

## Summary

Drainage for land treatment sites must be evaluated with respect to the purpose the system is meant to achieve. Off-site drainage controls the flow of storm runoff onto the site or groundwater incursion into the soil within the site. On-site drainage is employed for a variety of reasons. These two areas of drainage control, on-site and off-site, must be designed as a system to obtain the desired effluent quality from the land treatment system.

Surface drainage techniques often used for the control of water include diversions, random surface drains, waterways, and ditches. Subsurface drainage is generally accomplished through the use of drain piping with materials such as plastic, clay, and concrete. These techniques will generally make up the drainage system.

The objectives of drainage systems as they relate to land treatment sites are discussed, including some flexible operating patterns which can be incorporated through the use of on-site drainage.

Factors affecting drainage which must be obtained during reconnaissance surveys fall into four major categories: topography, geology, man-made obstructions, and soils. This type of information is generally available through various government agencies as well as private and public utilities and corporations. Many information sources for drainage overlap those used for other aspects of site evaluation. The degree of accuracy required of the information is dependent upon the stage of drainage evaluation or design.

Costs incurred for drainage control are dependent upon the four factors previously mentioned: topography, geology, man-made obstructions, and soils as well as the type of drainage system selected and the equipment used to install it. An example of the drainage that can be used with land application systems is the 5000 acre layout at the Muskegon Wastewater Management System. Drainage was provided at a cost of $4.3 million dollars ($860/acre) which reflects capital expenditures only (Demirjian, Y,A., 1975).

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## Objectives

Upon completion of this module, the reader should be able to:

1. List and discuss the two major objectives of off-site drainage.
2. Discuss several objectives of on-site drainage systems as they relate to land treatment.
3. Explain the use of drainage in the three operating options involving water table manipulation discussed in this module.
4. List and discuss the four main areas of site characteristics (besides volume of flow to be handled) in which information is required to design a drainage system.

## Introduction

Generally, large areas of land are required for land treatment sites. Usually these areas contain low spots, springs, and seeps which will require earthmoving or artificial drainage. Runoff of storm flow onto the treatment site from areas of higher elevation may have to be diverted, usually in channels, to protect the site from excessive hydraulic loads as well as erosive flows. Subsurface drainage may be required to lower the water table, extract the renovated water from the groundwater aquifer, or manipulate the water table for increased wastewater renovation. Therefore, both surface and subsurface drainage systems are required to perform various functions at land application sites. At a given site, it may be necessary to use a combination of the two to achieve the drainage objectives.

A drainage plan of the area under investigation must be made in order that the total drainage requirements may be identified and designed as part of the land application system. This plan should include surface and subsurface drains as well as the identification of an adequate outlet. An operational scheme must also be included where the water table is manipulated to achieve a higher degree of renovation. Maintenance of the drainage system once the land application site is in operation must also be considered.

Including a drainage system in the site planning can make an otherwise unsuitable parcel of land become a viable alternative. An example of such a site would be one in which all other factors are favorable except a high seasonal water table. The cost of drainage improvements would then be included in the economic analysis versus, for example, transportation costs for a more distant site not requiring extensive drainage.

The purpose of this module is to present drainage concepts in relation to their application in land treatment systems, not to provide all the background required to design drainage systems. Reference is made to detailed manuals or texts where necessary.

A discussion of the benefits of drainage to crop production on agricultrual land is found in the section "Drainage Requirements and Crop Water Tolerance" of Module 20, "Crop Selection and Management Alternatives". These reasons for providing artificial drainage improvements are listed in tabular form, along with the reaction of various crops to excess water in the root zone.

## Off-Site Drainage

Collection, transport, and disposal of runoff water which may enter the land treatment site from outside sources must be planned as a system. The objectives of this system are twofold:

The purpose of off-site drainage is to protect the system from erosion and excessive hydraulic load.

1. protection of the land treatment area from erosive flows
2. preclusion of additional hydraulic load through the treatment medium

### Diversion Ditches for Interception of Surface Runoff

Often, open ditches serve as diversions to protect lower lands from overland flow. These are generally dug across a slope, or at the toe of a slope with the borrow material diked on the lower side for efficient use of material (Figure 1). The bottom of the diversion terrace could extend quite deep to intercept a seep along a hard pan layer. Diversion terraces are generally graded and grass-covered so that the collected water may be delivered at non-erosive flows to a central discharge point. This discharge point is vital to the smooth operation of the whole surface drainage system, and adequate capacity must be provided in the outlet so that there is no backup and overflow of the channel at design flow.

Diversion terraces intercept runoff and deliver it to outlets at non-erosive flows. Outlets must be large enough to prevent backup.

The level of protection for which the diversions are designed depends upon what is to be protected. Roadways and equipment may require safeguarding against a 50-year - 24-hour rainfall runoff event, whereas a grassed slope may require protection from the 25-year - 24-hour rainfall runoff event. In any case, the level of protection and the amount of runoff expected must be identified.

The level of site protection desired and the amount of runoff expected must be identified.

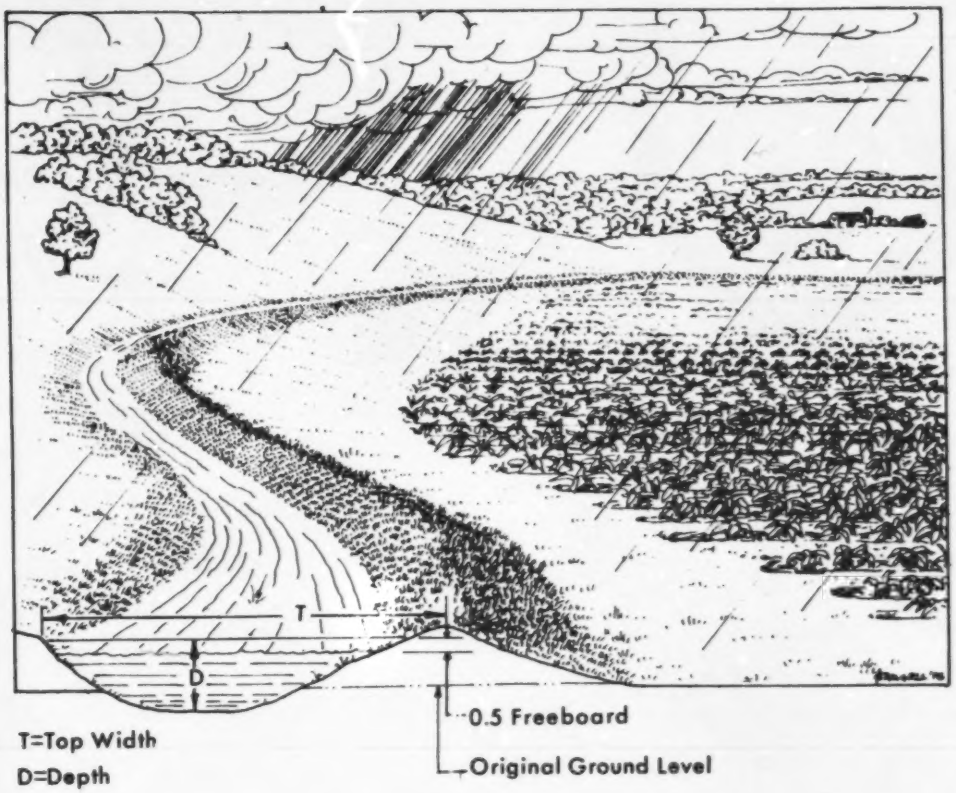


**Figure 1. A typical cross section of a diversion terrace protecting a cornfield from external sources of water.**

Module 8, "Climate and Wastewater Storage" presents guidelines stating that the design rainfall which must be contained on a site is the 25-year, 24-hour storm. In order to ensure that the on-site drainage system can achieve this goal, the site should be protected against at least this design flow entering from adjacent land. Some excess capacity in the off-site channels is good design practice.

The off-site drainage system ought to protect against at least as severe a storm as the on-site system is designed to handle.

Runoff from Storms of Varying Duration Should be Evaluated

In addition to the 25-year, 24-hour rainfall, peak flows can occur from intense storms of much shorter duration. Depending on the conformation of the land, such a stormflow may necessitate a larger channel than is required for the longer, less intense rainfall.

Peak flows can exceed the design storm expectation if there is a brief, intense storm.

Design flows for storm runoff of this type are usually obtained from the rational formula, $Q_p = KiA_d$ (Linsley and Franzini, 1964), where $Q_p$ is the peak runoff in acre-inches per hour, K is a runoff coefficient which relates the runoff from a given surface to an impervious standard i is the intensity of rainfall (inches per hour) which can be expected at a given location for a duration equal to the "time of concentration" ($t_c$) of the watershed. $t_c$ is derived from the watershed characteristics. $A_d$ is the watershed area in acres. Since 1 acre-in per hour equals 1.008 cubic feet per second, $Q_p$ is generally assumed to be expressed in cfs.

This equation is a very simple one, but it does require some discretion in its use. Experience with the rational formula and runoff calculation in general is very helpful, because assumptions must be made about some of the factors in the formula.

Rainfall runoff from land adjacent to the site should be computed according to some recognized method.

Time of concentration is taken as the time required for runoff to reach its peak value when applied to a watershed at some constant rate. For an impervious surface, this peak runoff would equal the rainfall rate. For most watersheds, $t_c$ would consist of two components-overland sheet flow and channel flow. Formulas are used for the overland flow component which take into account slope, length, and retardance coefficient, a measure of flow resistance offered by several types of ground cover. Channel flow $t_c$ is computed by length of longest channel divided by average velocity at bankfull stage.

Intensity of rainfall is taken from rainfall data for a given area using the duration equal to the computed $t_c$. Curves are usually available from city engineering or highway department offices. The coefficient of runoff is taken from a table of values for various ground surfaces, and there is usually some room for assumptions in choosing

Intensity of rainfall for particular durations are available from city engineering or highway department offices.

this factor. Other formulas are also used in stormflow computation, and a full discussion of runoff rate and volume calculations is found in Schwab, et al., (1966).

Should the runoff calculated for a short, intense rainfall be large enough to exceed the capacity of off-site channels designed on the 25-year, 24-hour basis, excess capacity should be designed to contain the higher flow, if it is at all economically sound to do so. Thus, localized flooding or excess surface water on the land application site can be avoided.

If a brief intense storm is calculated to give more runoff than the design storm, the off-site channel capacity may have to be greater.

Once the flow is determined, surface channels should be designed according to standard engineering practice, allowing for proper side slopes, bottom widths, freeboards, etc. as shown in numerous texts. One excellent ditch design reference, available free on request from the Soil Conservation Service, is SCS (1971) Chapter 5.

Interceptor Drains to Exclude Excessive Groundwater

Often seeps occur along the toe of a sloping land surface. These seeps are generally the result of the water table surfacing due to rock or hard pan layers constraining flow. Interceptor drains (Figure 2) are an alternative to collect and transport this water away from the land treatment site, most often to a surface discharge channel or natural stream.

Interceptor drains lower the water table.

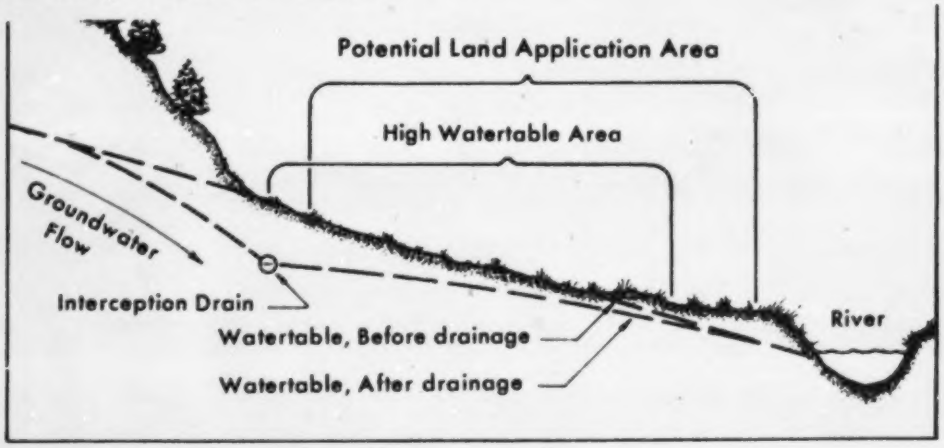


Figure 2. Interceptor drain collecting groundwater flow thus lowering the water table.

Groundwater flow enters an interceptor drain line either through perforations in the pipe or through the joint between sections of the pipe. The term "tile drain", which is still in wide use to refer to drainage pipe, refers to the fact that for many years almost all such pipe was made of ceramic tile. Other materials now commonly used include concrete, bituminous coated fiber, plastics, asbestos cement, aluminum alloy, and steel. Various factors enter into the selection of the proper pipe for a particular application, including climatic conditions, soil chemical characteristics, depth requirements, and cost including installation. Specific information on drainage pipe is available from many sources, including SCS (1971) Chapter 4. This reference, and the qualified drainage engineers on the staff of the various Soil Conservation Service local offices, can also provide a wealth of information on pipe laying techniques, use of filter envelopes and other mechanisms of improving drainage system performance, and other information which is useful and tailored to the local situation. This type of data is outside the scope of this module.

There is wide choice in interceptor drain pipe material. Factors such as soil chemistry, depth requirements, climatic conditions, and cost influence the choice.

Advice on specific drainage questions should be sought from drainage experts. Written referances give general information for system design.

Table 1 briefly summarizes some advantages and disadvantages of commonly used drainage pipe materials.

Table 1. Drainage Pipe Materials

| Material | Advantages | Disadvantages |
|---|---|---|
| Ceramic tile | -Resists action of acids and sulfates<br>-Smooth walls ease flow in smaller sizes | -May absorb excess water<br>-May be damaged by freezing and thawing |
| Concrete | -Convenient length for use as culverts<br>-Can be poured in place | -May be damaged by acids and sulfates<br>-Heavy |
| Bituminized fiber | -Light weight<br>-Corrosion resistant | -May soften in sun<br>-Needs smooth bed |
| Plastics | -Ease of handling<br>-Light weight<br>-Roll type can be installed by machine | -Must be carefully bedded |
| Asbestos cement | -Not subject to chemical damage<br>-Broad range of sizes | -Relatively costly<br>-Careful handling important |
| Aluminum alloy and steel | Good for: road crossings<br>-unstable soil<br>-outlets for other pipes<br>-surface installations | -Expensive |

## On-Site Drainage

On-site drainage may be accomplished through the use of surface or subsurface drains. These, singly or in combination, may be used to drain isolated springs, low spots, or seeps; or they may be used in parallel fashion in a total site drainage scheme. The objectives of a system may include the following:

1. elimination of wet areas caused by springs or seeps
2. elimination of septic pools and anaerobic conditions to prevent odors
3. elimination of standing surface water to decrease potential runoff of pollutants
4. lowering of the water table to make a greater depth of the soil treatment medium accessible
5. water table manipulation for increased wastewater renovation, e.g. nitrogen removal
6. drainage outlet control of retention time through the site
7. switching of application basins through manipulation of the underdrain system

Objectives 5-7 are examples of operational flexibility which can be built into certain systems for special applications, which will be discussed in subsequent sections. The first four objectives conform to standard agronomic practice, which aims to maximize crop production by eliminating surface ponding and waterlogging of the soil. In order to establish a good stand of most crops, alleviation of waterlogged soil conditions in the early growth stage is essential. This enables plants to develop healthy roots so they can continue to transfer sufficient nutrients to the upper plant parts for full development when the water table naturally drops in the summer. Therefore, drainage systems designed to lower the water table may contribute an agronomic benefit to the land as well as making land application feasible on a marginal site. Thus, in cases where the waste treatment authority contracts with private farmers to operate application sites on their farms, the decision to install such drainage for waste

A well designed drainage system will increase the acceptability of a site for waste treatment and crop production. This latter aspect could be a key point in convincing landowners to lease their land for a site.

treatment reasons may also be greeted with favor by the farmer. He would derive benefit for future use of the land by improving his marginal fields.

Drainage systems to achieve objectives 4-7 are subsurface systems. Elimination of wet areas and surface ponding, however, can be handled by totally surface systems, subsurface piped systems with risers and ground level inlets, or systems incorporating both surface ditches and subsurface piping.

Both surface and/or subsurface drainage methods can be used for eliminating wet areas and ponding.

Surface drainage schemes can be laid out either on a grid (or similar configuration) as in Figure 3, or as a random system (Figure 4).

Complete Coverage Surface Drainage

The farm drainage system illustrated in Figure 3 shows the types of surface drainage ditches in common use on agricultural land. In the case of land application sites, the rows could act as distribution channels in surface irrigation. Application could also be by a spray system. The field ditches act as collection channels and the field laterals and farm lateral act as disposal channels. The laterals can also lead to holding basins for recycling through the system. Collection channels must be graded smoothly with the field slope so that they may accept non-erosive flow of water over their sides. Disposal channels are built for optimum flow characteristics and should receive flow only at junctions with field drains This sort of system would be typical of farming operations in wet climates. It would also be suitable for overland flow wastewater treatment systems which would use close growing crops rather than the row crops indicated in Figure 3.

Drainage ditches that are laid out in a grid pattern can also be used for wastewater application and/or collection.

Disposal channels are built for optimum flow and should receive flow only at junctions with field drains

Random Field Drains for Isolated Springs, Low Spots, or Seeps

Random field drains are used to drain isolated wet spots within the land treatment area, to prevent

odors, to decrease the pollutant runoff potential, and to maximize the use of the land area. These drains may be surface or subsurface installations. Figure 4 illustrates a surface random drain system, while Figure 5 shows a hypothetical layout utilizing both surface and subsurface drains. Whether or not the discharge from this type of drain is recycled through the treatment medium is dependent upon the water quality realized and the water quality standards of the receiving sink. Handling clean water through the waste application system constitutes an unnecessary cost which must be avoided where possible.

When subsurface installations are used to drain springs, seeps, or low spots the discharge may be recycled or released depending upon quality.

Parallel Drains for Water Table Control

Wastewater renovation is a function of the amount of surface contact with the treatment medium as well as a function of contact time. Some soils may not offer an acceptable depth for adequate renovation due to bedrock, hardpan layers, or high water table. Under high water table circumstances, drainage of an entire site may be advantageous. In lowering the water table, more of the soil profile may be used for wastewater renovation.

Lowering the water table may allow more of the soil profile to be used for treatment.

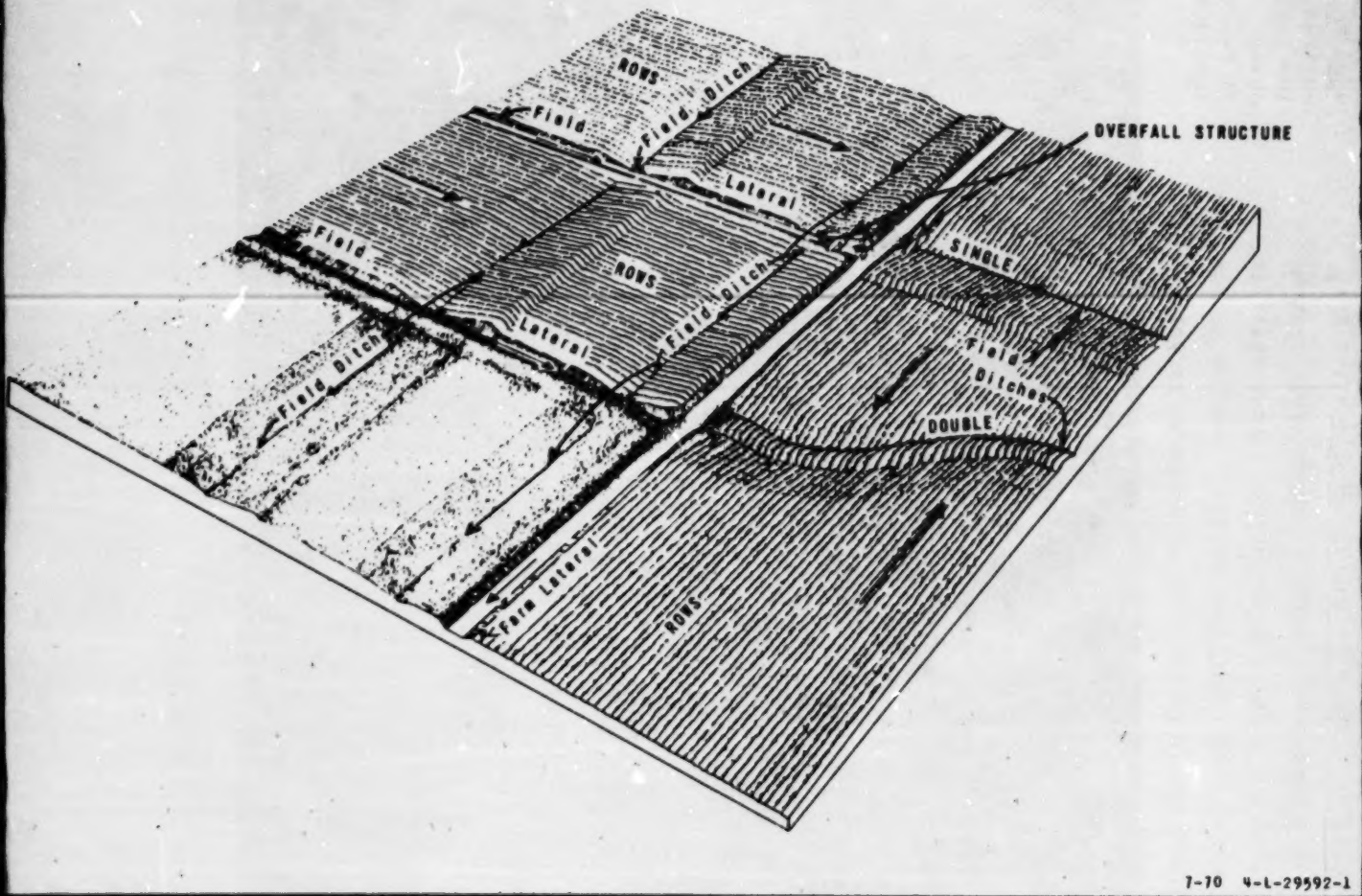




Figure 3. Typical layout-individual farm surface drainage system (Where the ground surface is undulating, ditches and drains will meander) (SCS, 1971)

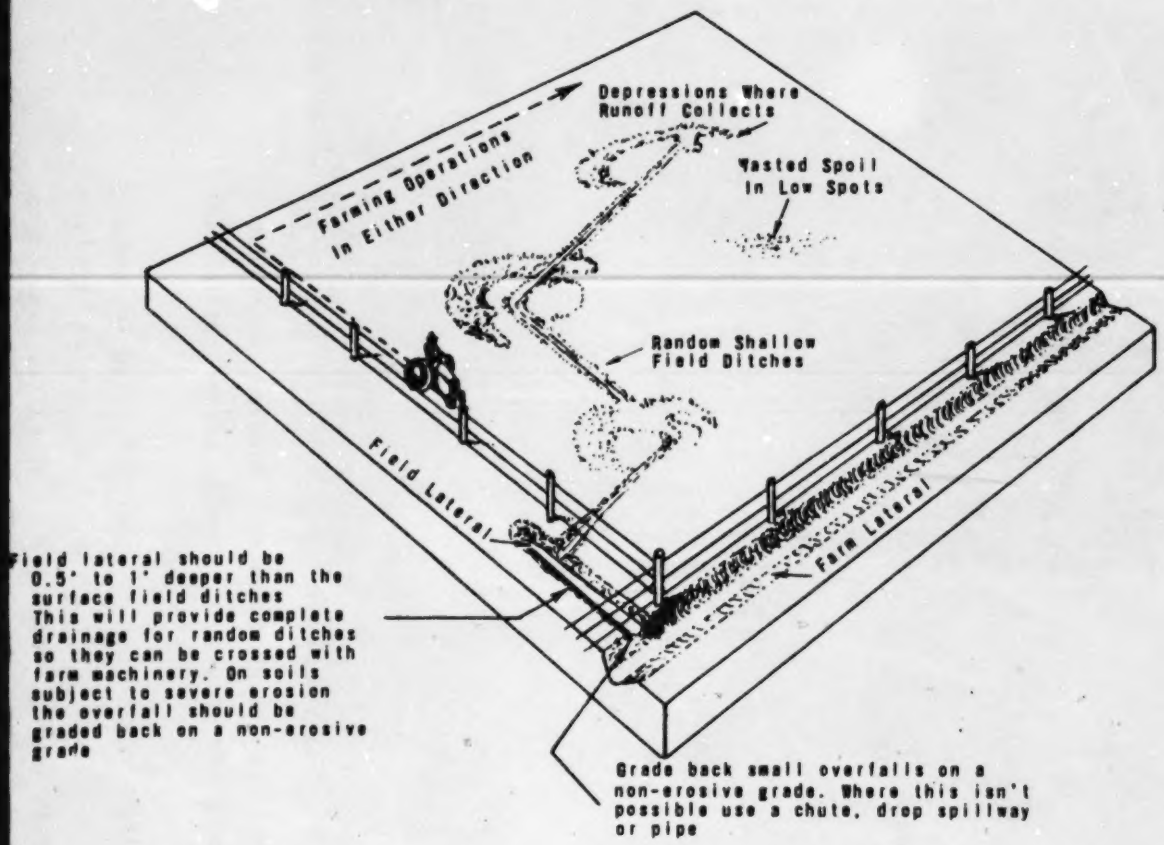
Depressions Where Runoff Collects
Farming Operations In Either Direction
Wasted Spoil In Low Spots
Random Shallow Field Ditches
Field Lateral
Farm Lateral
Field lateral should be 0.5' to 1' deeper than the surface field ditches This will provide complete drainage for random ditches so they can be crossed with farm machinery. On soils subject to severe erosion the overfall should be graded back on a non-erosive grade
Grade back small overfalls on a non-erosive grade. Where this isn't possible use a chute, drop spillway or pipe
7-70 4-L-29592-2

Figure 4. Random system of ditches draining surface depressions in a field. (SCS, 1971).

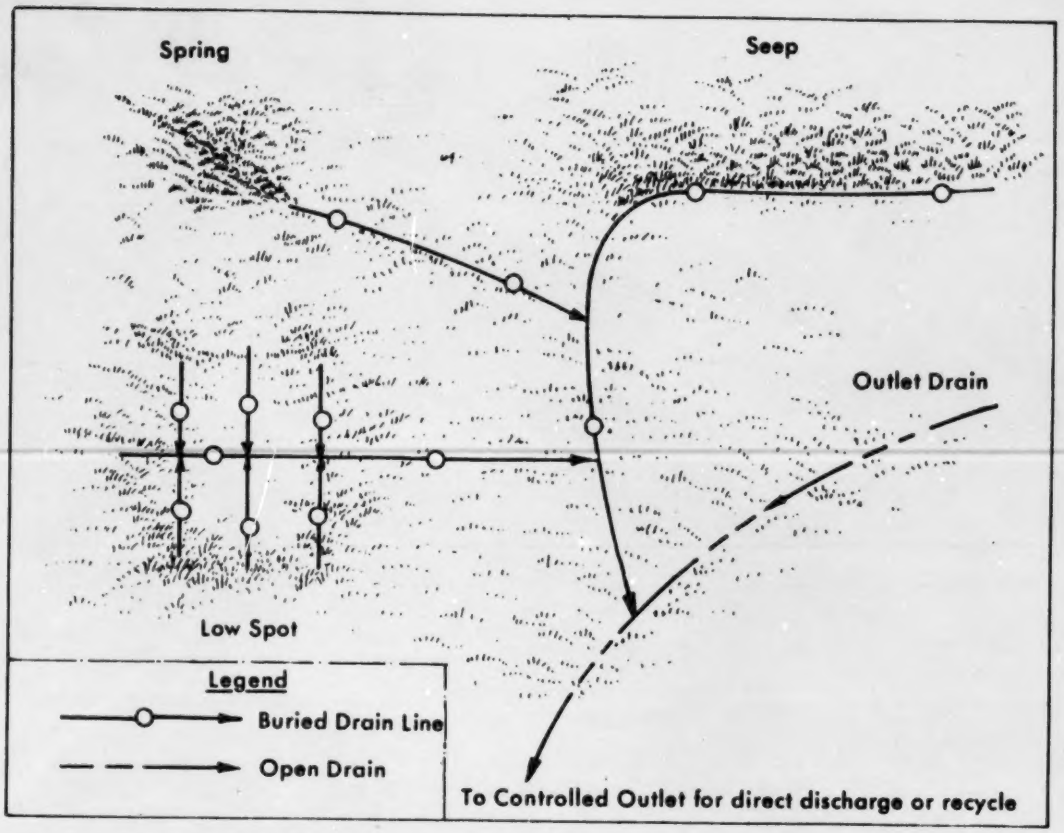


Figure 5. Random field drains servicing spring, seep, and low spot.

The depth of soil required for adequate renovation is dependent upon the influent waste characteristics, the renovation capacity of the soil profile, the required effluent quality, and the treatment alternative. The soil profile and its renovation capacity is highly variable. For this reason, many state laws and regulations require 5 to 10 feet depth to groundwater. However, most states reserve the option of a site specific investigation and evaluation.

The depth to groundwater for land treatment may be regulated by state laws or guidelines.

Subsurface drain lines are generally used to lower the water table over large areas. These systems utilize parallel drain laterals to collect the water. Transportation of this water from the site could be through open ditches as well as subsurface drains. Figure 6 outlines several configurations of drainage collection systems used for this purpose.

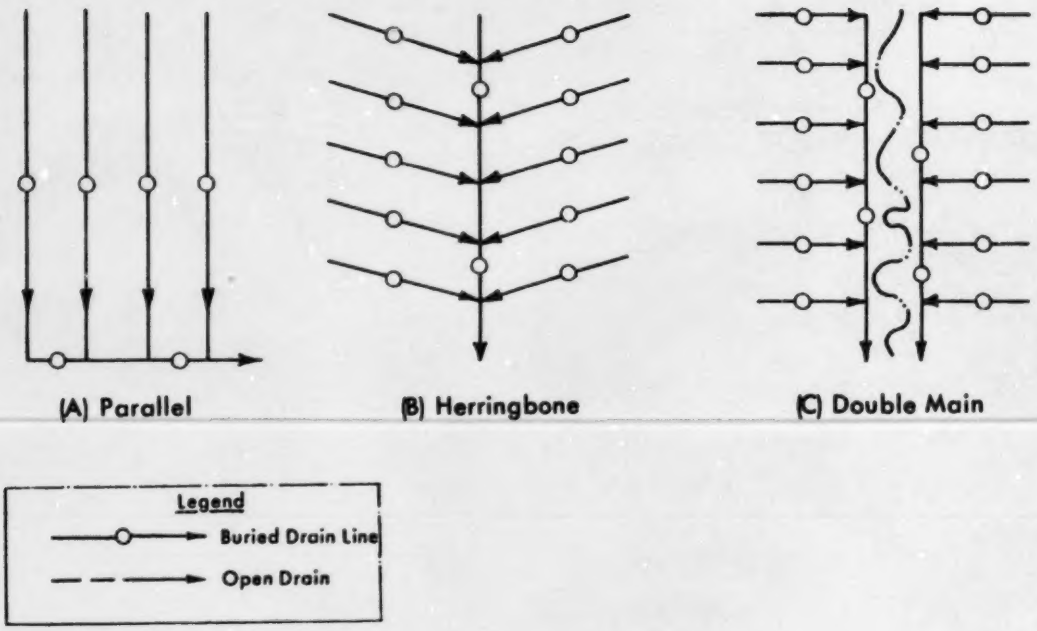


Figure 6. Several types of drainage collection systems utilizing parallel buried drains.

## Drainage for Water Table Manipulation Resulting in Increased Renovation and Contaminant Control

Nitrification-denitrification. Nitrification-denitrification may be controlled by manipulating the water table so as to enhance aerobic and anaerobic conditions in an alternating pattern in the soil profile. This can be accomplished by installing and operating a drainage system as discussed below.

Raising the water table by manipulating the drainage system encourages anaerobic conditions. These conditions favor denitrification.

The type of land application system selected will have a bearing on the feasibility of installing drainage for denitrification. Overland flow systems may require drainage for the control of wet areas due to seeps or springs. However, a large amount of water is not expected to penetrate the soil profile. Therefore,

drainage for denitrification would not be used in most overland flow schemes. In systems such as rapid infiltration and crop irrigation, penetration of water into the soil profile is expected, and the soil water level may be manipulated to encourage nitrification-denitrification schemes. In rapid infiltration systems enough water can be added on a frequent application cycle to encourage anaerobic conditions within the soil profile. However, in crop irrigation systems relatively small amounts of water are added, usually on a once-weekly schedule.

The water table must be relatively close to the soil surface (5 to 10 feet) for its level to be readily raised or lowered to meet the nitrification-denitrification operational mode. This manipulation of the water table may be accomplished by varying the elevation of the drainage system outlet.

The amounts of nitrate nitrogen and readily oxidizable organic compounds within the wastewater and the soil profile are of interest in nitrification-denitrification systems. As discussed in Module 15, "Nitrogen Considerations", the amount of denitrification obtainable is dependent upon the degree of initial nitrification and the amount of organic carbon left for denitrification.

Denitrification is dependent upon a supply of readily oxidizable organic carbon, high nitrate levels, proper pH and temperature, and low or zero oxygen concentration. The latter can result from restricted drainage. Under these conditions a facultative population of microbes utilizes the available carbon as a substrate and the oxygen in the nitrates for respiration, releasing the nitrogen as a gas.

Ion Exchange Important in Renovation Capacity

Ion exchange for the removal of metals and other substances is a major separation process that occurs in land treatment systems. Many soils consist of minute humus and clay particles which are negatively charged. Cations such as metals and ammonium are

attracted to these cation exchange sites. The amount of actual exchange that takes place is dependent upon, among other things, the amount of contact time between applied wastewater and the soil matrix. Through manipulation of a drainage outlet, this contact time may be modified to increase the cation exchange potential of the soil profile.

Raising the water table can increase contact time between wastewater and the soil profile. This may facilitate cation exchange for retention of metals and ammonium.

Groundwater flow control-After wastewater is applied to the soil surface, various phases of renovation are encountered. Pollutants are removed through filtering, ion exchange, microbial assimilation, and crop uptake. In some cases pollutants may not be removed adequately by land treatment and can enter the groundwater reservoir.

Bouwer (1974) has suggested a drainage system (Figure 7) to collect and recycle renovated wastewater from shallow aquifers. Figure 7A consists of two parallel strips from a rapid infiltration or crop irrigation system. Wastewater is applied in parallel strips along the soil surface. Upon infiltration, percolation occurs along the flow lines as illustrated in the figure. Once collected in the drain, the renovated wastewater may then be recycled to attain the desired effluent quality or it may be discharged directly into the receiving sink. Figures 7B and C illustrate an alternatively wet and dry cycling system utilizing the drainage collection system of Figure 7A. The flow of wastewater in the system is over a longer distance allowing for a greater travel time. In this manner, there is less danger of short circuiting. The exposure of the wastewater to the treatment medium is also increased.

Subsurface drainage can be used to collect wastewater for analysis and either reapplication or discharge. It can also be used to lengthen the soil contact distance, resulting in greater renovation.

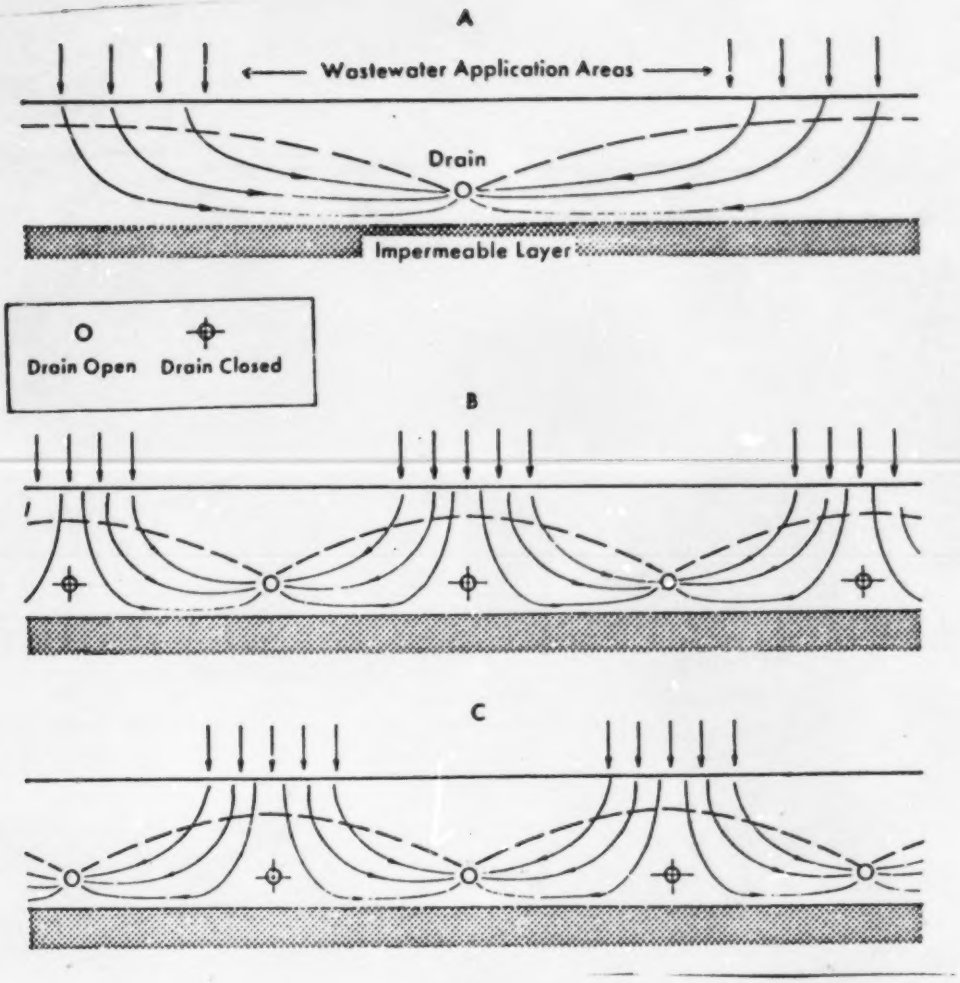


Figure 7. Rapid infiltration or crop irrigation scheme utilizing under drains for renovated water recovery.

Where deep aquifers are encountered, drainage through conventional drain systems is not feasible. Figure 8 illustrates an alternative utilizing parallel infiltration strips and recovery wells. Deep wells have been placed at strategic points in this system to control and collect the renovated wastewater. Although pumped drainage systems are high in initial and operating costs, the water table may be lowered to much greater depths than with other drainage methods, exposing deep strata which may be much more permeable than those nearer the surface (SCS, 1971).

Recovery wells can be used to collect renovated wastewater from levels lower than is feasible using drain lines.

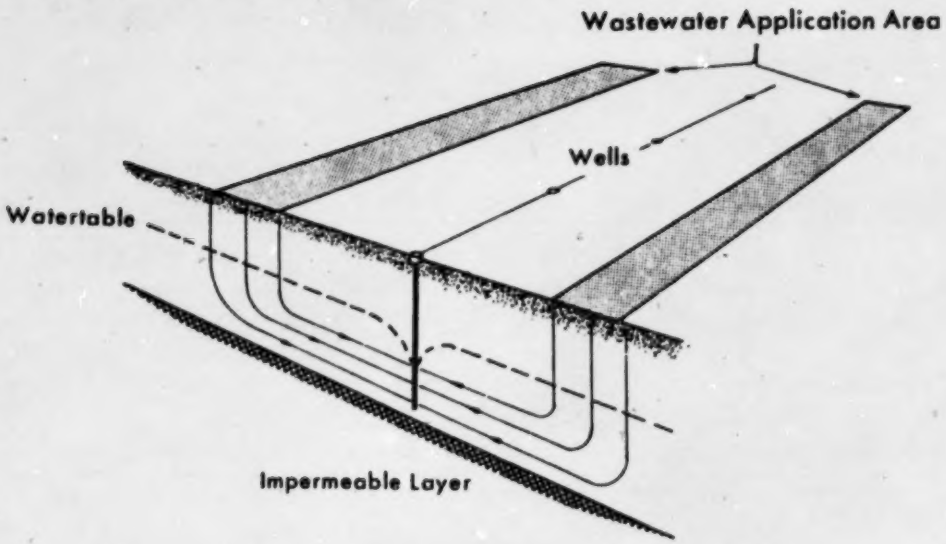


Figure 8. Rapid infiltration scheme utilizing wells for recovery of renovated wastewater.

For the most part, land application systems will be placed in rural areas. In these areas, shallow wells often are the main water supply for homes. A Means of controlling the groundwater flow away from a land application site may be desirable where rural water supplies, streams and recreational water areas are nearby. Drain lines placed between the land application site and the water source to be protected, as shown in Figure 9, may be a feasible alternative for adequate protection.

Recovery wells can be used to collect renovated wastewater from levels lower than is feasible using drain lines.

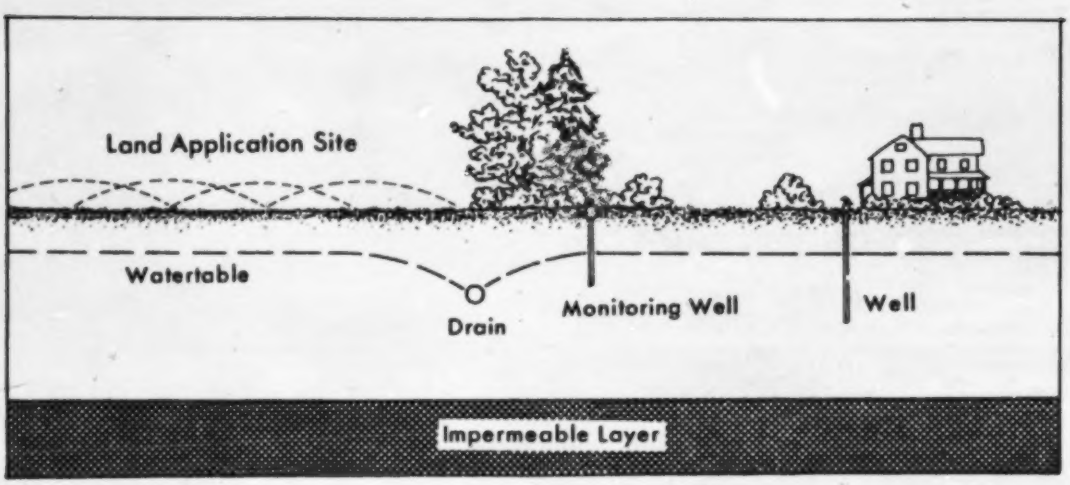


Figure 9. Drainage is provided around the perimeter of a land application site to protect a water supply.

## Reconnaissance Survey - Factors Affecting Drainage

Besides volume of flow to be handled, drainage system design is most influenced by the topography, geology, man-made obstructions (e.g., roads), and soils of the site. These four areas of concern must be investigated during the various stages of drainage planning. Their investigation will reveal the intricacies of the site under consideration so that feasibility and cost analysis may be obtained.

The topography of a site must be known for several reasons. Some of these include the following:

1. An adequate outlet for the drainage system in mind must be available. Although a pumped outlet is always possible, gravitational flow would more than likely be preferable. Topographic maps would provide insight into this requirement for initial planning.

2. In surface drainage systems, enough elevation head must be available to move the water at the desired rate but not so fast as to cause erosive flows. Site topography must be known for estimates in the areas of overland flow, channel and waterway flows, and limiting nonerosive flows.

3. In subsurface drainage the grade of the drain line is generally set by the elevation head available and the size of drain pipe. However, the distance to the drain line from the soil surface is critical where heavy equipment may drive over and crush a shallow drain.

A survey of the site must indicate:

a. the availability of a drainage outlet
b. the availability of enough elevation head for surface drainage
c. the material that must be moved to install the drainage system
d. man-made obstructions that might affect the drainage system

The geology of a site will reveal the type of material that must be moved to install drain lines as well as a profile of the site depicting probable causes of restricted flow of water. This information is necessary in the evaluation and design of a complete drainage system.

Man-made obstructions, such as roads, buried cables and pipes, diversions, dams, dikes, culverts, and bridges, must be pinpointed and assessed as to their role in the drainage scheme. Private and public roads, buried cables and pipes, dikes, and irrigation canals are not readily crossed without considerable expense. The capacities of

existing water conveying systems such as road ditches, diversions, canals, culverts, and bridges may need to be increased as the result of discharging additional drainage water. The effect of an additional load on the existing drainage system must be evaluated with respect to the increased hydraulic load. Considerable costs could be incurred through the replacement of road culverts and bridges, and the enlarging of existing ditches.

Many properties of the soil profile must be known in order to intelligently evaluate and design a drainage system. In surface drainage, the erodability of the soil must be known to prevent erosive flows from accumulating, whereas in subsurface drainage, the hydraulic conductivity of the soil profile must be estimated. These kinds of judgements can best be made by persons with experience in the soils and geology of the area under consideration.

Information Sources for Drainage Design Tie In With Those for General Site Design

Many of the sources of information mentioned in Module 2, "Site Evaluation" also yield data necessary for drainage system design. Aerial photographs, USGS topographic maps, SCS county soil survey reports, precipitation data, and crop yield data are discussed in Module 2. In addition, other data useful for drainage investigations are streamflow, river stage, and tide runs to evaluate flood hazard; soil conservation district work plans and old drainage surveys for ground levels and other information; and geologic and ground water surveys for subsurface and pumped flow system information. Field surveys must also be done, in conjunction with the other on-site engineering work, to isolate problem drainage areas or plan the layout of the system.

Module 2, "Site Evaluation" includes a full discussion of many of the information sources useful in drainage design.

Various texts deal with drainage. A recommended single source of information is the SCS National Engineering Handbook, Section 16, "Drainage of Agricultural Land". SCS drainage engineers may also be consulted.

Drainage contractors have the necessary experience and knowledge in the field to fulfill the requirements for most land application site work.

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M. M. Bogin edited copy and contributed to written and audio-tutorial modules. S. M. Dabney was the primary author of the Crop Selection and Non-crop and Forest Systems modules.

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# DRAINAGE FOR LAND APPLICATION SITES

## Objectives

Upon completion of this module, the participant should be able to:

1. List and discuss the two major objectives of off-site drainage.

2. Discuss several objectives of on-site drainage systems as they relate to land treatment.

3. Explain the use of drainage in the three operating options involving water table manipulation discussed in this module.

4. List and discuss the four main areas of site characteristics (besides volume of flow to be handled) in which information is required to design a drainage system.

# RETURN TO
# LESSON PACKAGE

Script to Accompany the A-T

DRAINAGE FOR LAND APPLICATION SITES

Module 21

January, 1978

DRAINAGE FOR LAND APPLICATION SITES

This lesson discusses the control of surface and groundwater flow using artificial drainage techniques (Slide 1). The objectives for this lesson are located in the envelope that is with the lesson box. Find and study the objectives (Slide 2). You may keep the objectives for reference during this module.

Slide 3 indicates the reasons for artificial drainage at a land treatment site. Not all of these factors may be operative at a given site. The purpose of this module is to present drainage concepts in relation to their application in land treatment systems, not to provide all the background required to design drainage systems. Reference is made to detailed manuals or texts for this background.

As Slide 3 indicated, drainage for land treatment is divided into two main categories - off-site and on-site. Off-site drainage protects the land treatment area from erosive flows over the site and can be used to preclude additional hydraulic load through the treatment medium (Slide 4).

Often open ditches serve as diversions to protect lower lands from overland flow. As Slide 5 shows, these are generally dug across a slope or at the toe of a slope with the borrow material diked on the lower side for efficient use of material. The bottom of the diversion terrace could extend quite deep to intercept a seep along a hard pan layer. As shown in Slide 6, diversion terraces are generally graded and grass-covered so that the collected water may be delivered at non-erosive flows to a central discharge point. This discharge point is vital to the smooth operation of the whole surface drainage system and adequate capacity must be provided in the outlet so that there is no backup and overflow of the channel at design flow (Slide 7).

It is suggested in the Climate and Wastewater Storage module (Module 8), that a land treatment site should be protected from the runoff from a 25 year, 24 hour storm (Slide 8). In order to ensure that the on-site drainage system can achieve this goal, the site should be protected against at least this design flow entering from adjacent land. Some excess capacity in the off-site channels is good design practice (Slide 9).

In addition to the 25 year, 24 hour rainfall, peak flows can occur from intense storms of much shorter duration. Such a stormflow may necessitate a larger channel than is required for the longer, less intense rainfall. Design

flows for the storm runoff of this type are usually obtained from the rational formula shown in Slide 10. $Q_p$ is the peak runoff in acre inches per hour, K is a runoff coefficient which relates to the runoff from a given surface to an impervious standard, i is the intensity of rainfall in in/hr which can be expected at a given location for a duration equal to the time of concentration, for the particular watershed characteristics. $A_d$ is the watershed area in acres.

For use with actual field conditions, the time of concentration is divided into components that depend upon sheet and channel flow as well as the ground cover of the slope. The intensity of rainfall can be obtained from city engineering or highway department offices. The runoff coefficient is taken from a table of values.

Slide 11 shows the possibilities for the 25 year, 24 hour storms. Much more intense storms can occur in short periods of time and still not exceed the 25 year, 24 hour design storm recurrence. Should runoff calculated for a short, intense rainfall be large enough to exceed the capacity of off-site channels designed on the 25-year, 24-hour basis, excess capacity should be designed to contain the higher flow, if it is at all economically sound to do so. Localized flooding or excess surface water on the land application site can, thereby, be avoided.

Seeps, as shown in Slide 12, often occur along the toe of a sloping land surface. These seeps are generally the result of the water table surfacing due to rock or hard pan layers constraining flow. Interceptor drains, or ditches are an alternative to collect and transport this water away from the land treatment site, most often to a surface discharge channel or natural stream.

Groundwater flow enters an interceptor drain line either through perforations in the pipe or through the joint between sections of the pipe. The term "tile drain", which is still in wide use to refer to drainage pipe, refers to the fact that for many years almost all such pipe was made of ceramic tile. Other materials now commonly used include concrete, bituminous coated fiber, plastics, asbestos cement, aluminum alloy, and steel. As indicated in the table in Slide 13, various factors enter into the selection of the proper pipe for a particular application, including climatic conditions, soil chemical characteristics, depth requirements, and cost including installation.

The objectives of on-site drainage are indicated in Slide 14. These objectives may be achieved through the use of surface or subsurface drains, or a combination of the two. Subsurface drains, however, are generally easier to maintain and will not cause channelling or shortcircuiting of the wastewater renovation.

These objectives conform to standard agronomic practice. As in agriculture, achieving these objectives could result in the development of an effective treatment site, on land that would not generally be considered suitable.

Random field drains are used to drain isolated wet spots within the land treatment area, to prevent odors, to decrease the pollutant runoff potential and to maximize the use of the land area. Slide 15 indicates a random system of surface ditches. With surface drains the collected water would probably have to be recycled through the land treatment system. Slide 16 indicates a random system using a combination of surface and subsurface techniques. The collected water, depending upon its quality, may not have to be recycled through the system.

Under high water table conditions, wastewater may not have enough contact time with the soil for effective renovation. Under these conditions drainage of an entire site may be advantageous. In lowering the water table (Slide 17) more of the soil profile may be used for wastewater renovation which also can result in a longer contact time.

Subsurface drain lines are generally used to lower the water table over large areas. These systems utilize parallel drain laterals to collect the water. Transportation of this water from the site could be through open ditches as well as closed drains. Several configurations of subsurface drains are shown in Slide 18.

When using subsurface drains, it may be necessary to use either a filter or an envelope or both. A filter, like the one shown in slide 19, is used to prevent fine grained material from entering the drain. Filters can be made from well graded sand and gravel, organic soil or top soil, fiberglass or plastic.

Envelopes are materials placed around drains to improve the infiltration rate in the immediate area of the drain. As the table in Slide 20 indicates, envelopes are not required where a filter is used since a filter can serve a dual purpose. Notice that the table also indicates minimum velocities for flow in a drain line. These velocities are the ones that will prevent the deposit of sediment in the line. When a filter is used these velocities do not have to be maintained.

Lowering the water table will not only result in more soil contact for the wastewater but will also improve crop yields. This improvement will result in a greater amount of nutrients being taken up by the crop (Slide 21). The improvement in the land due to drainage being added could also be the difference between a successful lease arrangement with a farmer and an unsuccessful lease arrangement.

The farm drainage system illustrated in Slide 22 is one for relatively impermeable soils. It would thus be suitable for an overland flow system. It could serve a dual capacity as a drainage and as a wastewater distribution/collection system. The field ditches would in this case act as distribution points by siphon tubes and collection channels. The field laterals could be used to distribute wastewater to the field ditches and to receive renovated water. The farm lateral would act as a disposal ditch. The farm lateral disposal ditch would only receive water at junctures with the field laterals, since they are designed for optimum flow rather than for receiving water over their entire length. The system for an overland flow site might look like the one in Slide 23. The wastewater could be applied by sprinkler with the ditches being used for collection only.

The previous sections have considered the standard purposes of drainage whether for a farming operation or for a land application site. Drainage can be employed, however, to provide operational flexibility that is specific to the land application of wastes and to land treatment sites. The objectives for these operations are indicated in Slide 24.

The scheduling and control of nitrification-denitrification and an increase of wastewater contact time can be manipulated through variations in drainage (Slide 25). This would be possible for relatively level irrigation sites and rapid infiltration sites. The manipulation of the water table can be accomplished by manipulation of the elevation of the infiltrate in the drainage outlet, as indicated in Slide 26.

Nitrification is accomplished through aerobic conditions. With the lowered water table ammonium would be transformed to nitrate, as indicated in Slide 27. This nitrate would be readily leached at the head of the next application. If the water table were raised, however, at the beginning of the subsequent application, then anaerobic conditions would result. With a supply of organic carbon, proper pH and temperature, denitrification would predominate, as indicated in Slide 28. The nitrogen would be released as a gas.

The temporary raising of the water table would also result in longer contact time between the metals in the wastewater and the cation exchange sites in the soil. This might increase the cation exchange potential of the soil at the same time as denitrification is being encouraged (Slide 29).

After wastewater is applied to the soil surface, various phases of renovation are encountered. Pollutants are removed through filtering, ion exchange, microbial assimilation, and crop uptake. In special cases, pollutants may not be removed adequately by land treatment and can enter the groundwater reservoir. One suggestion for a drainage system that would collect and have the potential to recycle renovated water from shallow aquifers is indicated in Slide 30. This system consists of parallel strips on which the wastewater is applied. Upon infiltration, percolation occurs along the flow lines illustrated in the slide. Once collected in the drain, the renovated wastewater may then be monitored and then either recycled or discharged into the receiving sink. This system would not be suitable for an overland flow system, since there is very little infiltration and subsequent percolation of the wastewater.

The diagrams in Slide 31, illustrate an alternately wet and dry cycling system utilizing the drainage collection system of the previous slide. The flow of wastewater in the system is over a longer distance allowing for a greater travel time. In this manner, there is less danger of shortcircuiting. The exposure of the wastewater to the treatment medium is also increased.

When deep drainage is necessary, conventional subsurface systems are not feasible. Slide 32 indicates an alternative utilizing parallel application strips and recovery wells. This system could be used for a rapid infiltration primary step in a land treatment system. The partially renovated wastewater, probably still unacceptable in nitrogen level, could be applied to crops through irrigation for complete renovation. Although pumped drainage systems are high in initial and operating costs, the land necessary for the total land treatment system could be cut significantly, resulting in a cost effective system with a very high degree of renovation capacity.

The four factors shown in Slide 33 all influence drainage design to a great extent. These areas -- topography, geology, man-made obstructions, and soils must all be investigated during the drainage planning.

The topography of the site will lead to decisions concerning the variables shown in slide 34. An adequate outlet that can drain the collected water by gravity is preferable to a pumped outlet. A study of the topography of a site will help locate a potential outlet. The drainage must be planned so that the water is delivered to and through the ditches at a rate that will not cause erosive flows but with enough head to remove the water. Finally, study of the topography

will indicate the distance from the soil surface to a subsurface drain line. This distance is critical in land treatment. If the distance is too short there may not be enough soil contact for adequate wastewater renovation and the groundwater may be too close to the soil surface.

The geology of the site will indicate the type of material that will have to be moved in installing a drainage system. The geology could also indicate the reasons for a restricted water flow (Slide 35).

Man-made obstructions including roads, bridges, buried cable, culverts and existing drainage systems must be pinpointed and assessed as to their role in the drainage scheme. Some of the obstructions could cause considerable expense if the drainage system must cross them (Slide 36).

If the drainage system from a land treatment site ties into an existing drainage system or even an existing natural waterway, the effect of the increased load on the existing systems must be assessed (Slide 37). Considerable expense could be incurred for the enlarging of culverts, existing off-site ditches, and stabilizing of the banks of the receiving stream to handle the increased load.

An assessment of the soils would indicate the maximum slope allowable that would not cause erosion & the hydraulic conductivity of the soil profile. The knowledge of these factors is important for surface and subsurface drainage systems. These kinds of judgements must be made by experienced drainage engineers familiar with the soils and geology of the area under consideration (Slide 38).